Testimony

Technologies for Border Security

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Chairman Boehlert, distinguished members of the House Committee on Science. I am honored to be asked to share with you my thoughts on the difficult topic of border security. To successfully protect our borders, yet remain within the limits of acceptable behavior of a democratic society is indeed a challenge.

To set the record, my background is in the development of technology to support military operations, based on 24 years of an Air Force career involving both operational and technical experience, followed by a second career in unmanned aerial vehicles (UAVs) and associated sensors and communications. Many of the systems lessons learned, as well as the technology developments, could contribute to the border security problems. My expertise is not the entry-point problem; I concentrate on the remote border problem.

Overview

The detection of border security violations has some similarities to the military border and area security challenges faced in Iraq and many other locations today. The differences are sufficient, however, that the system solutions are quite different in most cases. But, the technologies that have been developed and tested in military applications deserve consideration for homeland security, and the benefits and savings achieved by joint endeavors are significant.

In this paper, I attempt to review the technologies that, in my opinion, offer promise for significantly improved detection of border incursions. I will urge the homeland security and military laboratory teams to work together on these technologies.

A Context

I was asked to make assessments and compare, or evaluate technologies for border security. I find it most useful to consider technologies in the context of system concepts, and hence I would like to spend a few moments on the system aspect.

Border security is much like what the air forces call time-critical targeting. In the battlespace, a detected target must be attacked within a time frame (typically 10 minutes) determined by the possibility that the target will act or escape or both. The 10 minutes must be budgeted across numerous actions - Find, Fix, Track, Target, Engage and Assess.

In the case of border security, the objective is to intercept the detected intruding individual or vehicle before it can escape. --- Detect, locate, identify, decide, intercept. Once again, the time must be budgeted across these elements. If a human moves at 5 mph, you have just 12 minutes to catch that human if you want to limit travel to 1 mile from the border. I say this to emphasize that one minute saved in the detection and reporting process is a minute that the border agent has to get to the point of intrusion.

Human eyes and reasoning are essential in order to avoid fratricide --- but a system of shoulder-to-shoulder border agents is not possible, and it is not practical to continuously watch images of the entire border from airborne or surface sensors 24/7 across 8000 miles of border on the chance an intruder will be seen. Though a bank guard can view the few camera images of the bank access points, the vault, and perhaps the cashiers, the problem of monitoring sensors that may themselves be moving (creating a dynamically changing background), and the large area being guarded suggest a challenging situation. Yet, direct viewing or high resolution imagery is the only acceptable means of verifying that an unwanted intrusion has occurred. Automated target recognition (ATR) techniques may be able to determine that a human has been detected, but nothing more about identification or intent, given today's state-of-the-art.

I see no magic -- no single solution --- The system solution must be a layered sensor approach, tailored to the nature of the specific border situation. It must include:

- An inter-agency information system that can point to likely areas of intrusion
- A "trip-wire" to detect an intrusion and alert the system. A means to aim or focus an imaging sensor at the point of intrusion or other alerting cues
- A communication of an image containing the suspected intruder to a human agent for confirmation
- Collaboration of information from available sources, including the sensors, to expedite and improve the analysis process
- Presentation to the human decision maker in a form that is immediately sufficient to make an informed decision
- A means to expeditiously dispatch an agent to intercept the intruder
- An effective concept of operations, with the associated procedures and training to accomplish the above

There are a number of options for systems that meet this construct. Table 1 depicts some of the more powerful techniques.

Air intruders are an additional threat. These could be manned aircraft - perhaps a Cessna 172 piloted by a terrorist or a smuggler of narcotics or humans, or could be an unmanned aircraft, ranging in size and complexity from a miniature radio-controlled (RC) hobby model capable of carrying a few ounces of a deadly chemical agent to a Cessna 172 aircraft that has been rigged for unmanned operation, perhaps looking like a conventional manned aircraft with a mannequin in the cockpit seat but carrying 500 lbs of explosive. The Air Force Scientific Advisory Board has recently studied this problem[1].

Low and slow small aircraft pose unique challenges to our air defense system. Often the radar features that improve the ability to discern aircraft from background ground traffic by remove the slow movers (judged to be ground vehicles) on the basis of speed, would similarly gate out the

[1] Air Force Scientific Advisory Board Study, "Air Defense Against UAVs", 2006

UAVs and slow manned aircraft. Technology efforts are in order to address the processing of slow-moving small aircraft from background clutter.

The second key challenge for air targets is to determine intent. Given that the goal will be to force the air vehicle to the ground or shoot it down, we must be quite certain that this air vehicle has a hostile intent. This will be extremely difficult to determine and sensors are not available to accomplish the task. Intelligence will be the best indicator.

It will be especially important to provide air defense for the National Capitol Region and National Special Security Events, but borders must be considered as well.

The key to effective border surveillance and security is the intelligence that allows the security team to concentrate their search efforts and prepare the agent team. This cannot be over-emphasized, and includes intelligence information gained from the point of origin of the would-be intruders as well as the local intelligence information on staging areas and transportation means. The information may be gained over a significant time and geographical span, thus requiring both an effective network and an efficient correlation and dissemination process. This will be addressed in a later section

	Intruder				
	Human	Vehicle	UAV	Aircraft	Boat
Tripwire	Intelligence UGS EO/IR* GMTI Radar	Intelligence UGS GMTI Radar SAR Radar	Intelligence AMTI Radar	Intelligence AMTI Radar	Intelligence MTI Radar
Investigator	EO/IR	GMTI Radar SAR Radar EO/IR	EO/IR	EO/IR	EO/IR
Tracker	EO/IR	GMTI Radar SAR Radar EO/IR	AMTI Radar EO/IR	AMTI Radar EO/IR	EO/IR
Interceptor	Heli-borne Agent	Heli-borne Agent	Heli-borne Agent	Heli-borne Agent Fighter a/c	Heli-borne Agent

* where penetrations are concentrated and terrain/foliage permit

Table 1 – Techniques for Border Security

<u>Sensors</u>

Sensor technology for airborne applications is very well developed. The experiences in Iraq have demonstrated the advanced capabilities, and have generated yet further improvements in sensor systems, driven by the unique nature of the operations of the adversary. The military laboratories and industry have succeeded in gaining high resolution and compact packaging such that even small UAVs can carry the sensors and associated communications equipment. Table 2 shows the common sensors for this application.

Despite the fact that Unattended Ground Sensors (UGS) have been in development for many years[2], the state of the art is still lagging. The military services have been slow to develop and employ ground sensors, largely due to wariness as to the performance. The DHS Customs and Border Protection has reportedly placed some 11,000 (11,000 sensors spaced 100' means approximately 200 miles of ground-sensor monitored border) along the northern and southwestern borders. The false alarm rate has been uncomfortably high for sensor detections (animals, sun glint, etc.), and short battery life. Yet, their have been successes in other government laboratories[3]the commercial world including the development of grape-size sensors that are capable of self-organizing and robust networking. Table 3 provides advantages and disadvantages of the ground sensors.

Sensor Technique	Advantage	Disadvantages
Microwave MTI Radar	Excellent for detecting moving vehicles Good in weather Wide coverage area; good revisit Fair for vehicle target classification (w/HRR)	Marginal value in foliage Moving Targets (>MDV) only Limited capability against humans
Microwave Synthetic Aperture Radar (SAR)	Excellent for target classification Can be used with coherent change detection Good for target identification Good in weather	Marginal value in foliage Limited coverage rate Limited capability against humans
VHF Foliage Penetration (FOPEN) Radar	Good for detecting targets in foliage Can be basis for coherent change detection	Must operate at high grazing angles Long dwell time Not suitable for Tgt ID Limited capability against humans
EO/IR	Excellent for search small areas Best choice for detecting and tracking humans Best choice for target ID	Marginal performance in foliage Limited standoff distance Poor performance in weather
High Resolution LADAR	3D information for target ID Some foliage penetration	Small Field of Regard Marginal performance in weather Requires near-nadir look Requires close-in viewing
Hyperspectral Imaging	Good choice for facility detection Some foliage penetration Wide coverage area	Marginal performance in foliage Marginal performance in weather Requires near-nadir look Little data on detecting humans Poor target identification
SIGINT	Excellent for target ID Could pick up cell phones Good against aircraft data links	Unlikely personal signal emanation

Table 2 Key Airborne Sensors

[2] Perhaps one of the most widely-publicized failures of ground sensors was McNamara's attempt to stall supply flows along the Ho Chi Ming trail in Vietnam during that conflict
[3] Sandia National Laboratories has an excellent unattended ground sensor program

The false alarm rate was the Achille's Heel of the Southeast Asia application of ground sensors. More recently, the use of combination sensors (acoustic with seismic, for example) coupled with the progress in miniature processing hardware has shown great promise for low false alarm rates and long battery performance. This unattended ground sensors offer great promise for the monitoring for border intrusions, particularly in areas of dense vegetation and rough terrain.

Sensor Technique	Advantage	Disadvantages
Acoustic	Can detect human talk, breathing, motion Some target classification capability Suitable in heavy foliage Low operating cost	False alarms (as single sensor) Short Range Must be proliferated
Seismic	Can detect vehicle movement Some target classification capability Suitable in heavy foliage Low operating cost	False alarms (as single sensor) Short Range Must be proliferated
Tilt	Can detect large vehicle movement Some target classification capability Suitable in heavy foliage Low operating cost	False alarms (as single sensor) Short Range Must be proliferated
Magnetic	Good for detecting vehicles Some target classification capability Suitable in heavy foliage	False alarms (as single sensor) Short Range Must be proliferated Minimum communications
Multispectral	May provide target identification May be able to analyze dangerous items	Practicality questionable Limited range High communications requirements
EO/IR Imaging	Some target classification capability Low operating cost	
IR Non-imaging	Good for detecting warm bodies Suitable in medium foliage Low operating cost Minimum communications needs	False alarms (as single sensor) Short Range Must be proliferated

Table 3 Key Ground Sensors

There remain some important areas for further technology development. These tend to be more in the effective utilization of current sensing regimes

- **Multi- and Hyperspectral Imagery sensors for detection and identification of humans from airborne & UGS platforms**. Hyperspectral imaging offers the capability for identification of vehicles and, perhaps, humans. Moreover, it has shown promise in the identification pf packages and equipment being transported across borders.

- **Automatic Target Classification/Recognition techniques for EO & IR imagery**. The key to improving the efficiency of the limited number of border agents is to provide tools, such as the ability to scan images for humans or targets, to provide alerts with low false alarm categorization of the detection to the operator[4].

[4] The gambling casinos are now using automatic recognition techniques to spot undesirable participants.

- **Low cost, miniature, self-organizing, multi-sensor unattended ground sensors for detection and classification**
    - Acoustic
    - Seismic
    - EO
    - Imaging IR
    - Thermal IR

  This is perhaps the most promising area of technology development for the border surveillance. The sensing elements should be developed further to reduce size and battery power, and the processing of multiple complementary sensors for improved recognition or reduced false alarm rate is important.

- **Radar processing techniques for extracting small slow moving air and ground targets** from background low speed clutter. To date, MTI radar has been very effective in generating a situational awareness picture of a battle area, including the tracking of supply and equipment movements, but the slow speed and small cross-section of humans has limited effectiveness against humans. There is now hope for the detection of slow moving humans, and that area needs a technology investment.

<u>UAV Platforms</u>

The unmanned aerial vehicle has revolutionized the airborne sensor world. The aircraft and propulsions are mature and efficient. The vehicle mission management systems are reliable, partly due to improved hardware and software and partly due to the redundancy now being included in such aircraft as Predator B. They have the advantage (over manned aircraft) of long endurance – 30 to 50 hours. UAVs (like manned aircraft) tend to avoid failures once airborne, so the long endurance affects reliability as well.

The experiences of the Air Force and CIA in operation of long surveillance flights have been excellent. Predator and Global Hawk UAVs have been instrumental in gaining surveillance information around the clock. Both have been paired very successfully with attack aircraft. The Predator UAV has been successful in lingering in harms way to monitor suspected hideouts and laser designating targets for buddy strike. There have been cases of Predator surveillance of IED placement that resulted in many saved lives.

Even within the border patrol mission, UAVs have shown their value. The Predator B has been quite successful in its operation, being given credit for finding, tracking and the eventual capture of border crossing intruders. There have been a minimum of failures.

There are some advocates for aerostats as sensor platforms. In view of their inability to cope with higher winds, they seem to be achieving a 60 – 70% airborne rate. The UAV can move closer to an area to increase the look-down (grazing) angle, providing a better opportunity to view areas of vegetation, structures and terrain. Aerostats do not have that flexibility. In my mind, the low rate, combined with the need for substantial real estate and ground support equipment suggests the UAV for the mission.

An area of possible technology investment would be in the development of a hybrid aerostat that could morph to a parafoil kite when winds increased, and thus stay on station.

Table 4 shows the classes of UAVs suitable for border surveillance. Within the classes of possible UAVs for border security, the medium altitude endurance UAVs are most suited because they give the best trade between cost and endurance, with the border surveillance mission.

UAV Class	Examples	Payload (lbs)	Nominal Endurance (hrs)	Loiter Altitude (ft)	Loiter Airspeed (kts)
High Altitude Endurance	RQ-4A Global Hawk	1000	40	60000	250
	RQ-4B Global Hawk	2000	40	60000	250
Medium Altitude Endurance	MQ-1A Predator A	500 Internal 250 External	40	20000	85
	MQ-9A Predator B	750 Internal 3000 External	30	40000	85
Low Altitude - Medium	Lewk, Shadow	3000	4 - 8	10000	60 - 100
Medium Altitude - High Survivability	X-45, X-47	2000 - 5000	4 - 8	40000	300 - 500
Rotorcraft	Fire Scout, Hummingbird	500 - 1000	4 - 8	20000	60 - 200
Low Altitude - Small	Dragon Eye, FPASS, etc.	10 - 25	4	1000	40 - 60

Table 4 – UAV Classes

But there remain UAV technology issues deserving attention. Developing and operating UAVs present unique technology needs that go beyond the airframes and propulsion (and border surveillance flights):

- **Human-System Integration** - situational awareness, controls and displays, health management, and emergency procedures all require improved HSI
- **Detect, See and Avoid techniques** that are highly automated, vision-based systems are needed for UAV operations (and would benefit civil and military aircraft)
- **Automatic Traffic Alert and Collision Avoidance System (TCAS)** to do the tasks of the current TCAS, but translate the alerts into control commands suitable for avoiding collisions.
- **Automated landing systems** based on GPS but tailored for UAVs suitable for alternate precision landings at all airports
- **Automated voice** for declaration of position and intentions for lost-comm or other emergency situations, and for receiving emergency comms from disadvantaged nodes

- **Communications networks** that support machine-to-machine connectivity between ATC and UAV operators

One might have expected NASA to pioneer in developing many of the technologies listed above, as UAVs have both military and commercial applications in addition to those of the DHS. The UAV National Industry Team (UNITE) and the NASA ACCESS 5 Project were addressing the issues. With the reduction in the NASA aeronautics budget, ACCESS 5 was cancelled and it appears this will not happen. The military services and DHS are not funded to accomplish this either.

Certification of new systems will be rigorous, and is beyond the means of the UAV industry to fund. Here the Government should support this process, as it is long and costly.

Intelligence and Information Management

While I see much to be accomplished in the development of new sensors, our major shortfall, both in the military and in homeland border security, is the inability to effectively and efficiently deal with the large amount of information that is collected by our sensors or is available from other sources. This problem starts with the gathering of that information which will help us determine when and where sensors should be placed. This needn't be tapping of telephones or bugging residences, but is a matter of understanding the nature of the border (e.g., what is the terrain like; where are access points from highways; did it snow heavily in this area today), monitoring locations that might give indications of impending activity, and understanding the nature and behavior patterns of the individuals being sought. From this analysis, the limited resource budget of sensing systems and responding agents can be efficiently deployed. The notion of 24/7 surveillance of the entire border (or even 10% of the border) from the air is just not practical.

A good analogy is that of the ardent deer hunter. The deer hunter doesn't go out and sit at the first stump to wait for a deer. He (or she) has analyzed the general hunting area and selected an area most likely to be productive. Further analysis will tell the hunter which paths the deer will likely take under what conditions of weather and time of day. The deer doesn't worry about deer coming across a river or lake (though it sometimes happens). The hunter selects a location from which to observe, and uses his natural sensors wisely --- usually motion or noise are the tipoff, and the combination of the two – eyes sensing a movement as the noise emanates from the same spot. The hunter then casts a focused eyeball on the source of the movement or noise will confirm the target, and track that 'target" to the point of "intercept". Those same eyeballs couldn't possibly "image" all the area all the time.

The second information shortfall is that of communicating sensed data to a location(s) at which these data can be fused, analyzed, compared to stored data, stored, and presented in a coherent picture to the operator --- Thomas Friedman terms this "connect and collaborate". At the current time, information is available, but difficult to access. Information is located within various organizations and many locations. The information may be seconds old or years old. Data formats are different. Scales may be different on different images. The sources may have different levels of credibility.

The presentation to the decision maker is the final level of information management. The agent who must decide on a course of action has little time. He cannot search databases for relevant information. He, or she, must be presented with a fused picture that includes the material with appropriate indications of the reliability and nature of the information.. It may be necessary to discuss the information with another individual, so the information must be shared, whether the distant individual has a 21" screen at the command center or a PDA he has carried into the movie theater.

Little attention has been given to information management. The Air Force Scientific Advisory Board has recently completed a study[5] which makes the case for interoperability and the integration of information. In that study, it is pointed out that recent programs have created "stovepipes" of information, and solutions that lean toward integrating stovepipe systems will simply create further stovepipes. Instead, interoperability, achieved by metadata tagging (recording the data about the data – time and location, context, content descriptions, format) of all data can make it accessible to all. Moreover, the use if a service-oriented architecture providing the common tools for transferring, storing, fusing, and disseminating data assures a coherent management of the information.

I see the following areas as important information technology investment areas:

- **Communications networking**
    - Internet Protocol (IP) based communications sensor networking
    - Self-forming/self healing network management
    - Low power dynamically variable bandwidth comms for ground sensors
- **Data management and knowledge generation**
    - Descriptive metadata (i.e., content, context, and structure)
    - Semantic matching
    - Geospatial and temporal registration (co-registration of multi-sensor data)
    - Fusion
    - Real-time publish-subscribe-query service
    - Rules and tools for constructing metadata vocabularies
    - Automated metadata insertion into legacy databases
    - Rules for information sharing
    - Performance issues when scaling to many COIs and operational users
- **Visualization technology**
    - Aids to interpretation of large amounts of imagery
    - Aids to human interpretation of machine data
    - Aids to developing a concise and complete situational assessment picture in a timely manner for the decision maker

[5] Air Force Scientific Advisory Board, "Domain Integration", 2005

An Approach

It seems fitting to make some comment relative to achieving the improved border security capitalizing on the technology advancements.

In so far as developing the pertinent technologies is concerned, there are some fundamental science issues and as the science is matured, there are some prototyping and experimentation phases. To be sure, there will be a need to focus resources. I am concerned that the costs, both direct and overhead, associated with a new/expanded DHS sensors laboratory program will be significant. I see the need to partner with Service laboratories[6] in the technology program, not only in capitalizing on the lessons learned in long years of military endeavor in sensor development, production, deployment, and employment, but also in using facilities and other resources already in place. Some arrangement to, perhaps, provide funding and tasking to the military laboratories for sensor developments, or to co-locate DHS scientists with military laboratory teams should be pursued.

Testing should also be conducted in conjunction with military. Once again, sharing the cost of the tests will lead to joint management and sharing the results. Over and above that, there exist test ranges, experienced test managers, and procedures that could be used jointly to satisfy the needs of both DHS and the Military.

For the development of a system of advanced sensors, processing systems, and command *c*enters, I strongly recommend against turn-key integrated systems, Much of the past work addressing integration has actually been focusing on creating monolithic large scale systems. This a costly approach that inevitably restricts the introduction of new elements to those provided by the integration contractor. An end user only requires *virtual integration* – he needs to receive integrated data. He does not require actual domain integration nor does he have the responsibility and resources to accomplish it. For this reason, and many others, it is prudent to define an architecture that is flexible and is interoperable with the legacy systems. Quality of Service should be the metric, and hence a service-oriented architecture (SOA) is in order. A service-oriented architecture is an approach to defining integration-architectures based on the concept of service. A service is a collection of applications, data, and tools with which one interacts via message exchange

Integrate information, not systems

Finally, It is important to adopt an evolutionary acquisition approach. I quote from an Air Force Instruction:

"Evolutionary acquisition (EA) is a nontraditional, overarching acquisition strategy that a program can use to develop and field a core capability meeting a valid requirement with the intent to develop and field additional capabilities in successive increments"[7].

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[6] The partnering of the National Law Enforcement & Corrections Technology Center – Northeast Region with the Air Force Research Laboratory – Information Directorate is a good step.
[7] From Air Force Instruction 63-123, "Evolutionary Acquisition of C2 Systems", 1 Apr 2000

"The simple goals of EA for systems are to achieve modernization and deployment efficiently and quickly. Use of an EA strategy for systems will deliver a core operational capability sooner by dividing a large, single development into many smaller developments or increments. EA allows a program to quickly respond to changing conditions by allowing each increment to accommodate the following three activities: 1) develop new capabilities supporting the operational requirements and goals of the system, 2) exploit opportunities to insert new technologies that reduce cost of ownership or accelerate fielding of new capabilities resulting from experimentation or technology demonstrations, and 3) refine current capabilities based on user feedback, testing, or experimentation"[8]

Summary

There have been shown to be several border security technology areas worthy of increased emphasis by the Department of Homeland Security Customs and Border Protection service. For the most part, the developments are not breakthrough basic science, but rather a matter of applying science and making it available in a deployable form for application to the borders. More importantly, it is a matter of processing the raw data from multiple sensors, along with intelligence information data, in such a way as to extract the full content of knowledge from the data. This is not a job for sensor developers, but for information experts with a strong understanding of the sensor outputs. It seems we have radar experts and EO/IR experts and UAV experts, but lack in "find the human" experts.

This testimony is formulated to suggest the maturation of the technologies be conducted jointly with the U.S. military services. The techniques for the detection of humans entering the United States are, with minor variations in employment, essential to the protection of U.S. Forces and U.S. interests abroad.

[8] Ibid

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EDUCATION

Oklahoma State University	Ph.D., Electrical Engineering
Oklahoma State University	M.S., Electrical Engineering
Union College	B.S., Electrical Engineering

PROFESSIONAL SUMMARY

Dr. Worch is a senior systems scientist with over forty years R&D experience in the areas of avionics, communications, navigation, intelligence, command and control, emitter location, identification and surveillance; as well as overall military technology research and development management. He has been assisting in unmanned air vehicle (UAV) development programs and in UAV payload development efforts. Dr. Worch is a member of the Air Force Scientific Advisory Board.

Dr. Worch is a Research Scientist with George Mason University, conducting research in command and control systems concepts.

EXPERIENCE

Consultant (1994 to Present)
Dr. Worch provides assistance in operational, technical, and program analyses as well as both strategic and tactical sensor, electronic warfare, and C^3I architecture studies. He conducts analyses in time critical targets, UAVs, reconnaissance sensors, C^3I interface for advanced weapons systems, avionics, data links, smart weapons, navigation; LPI/LPE communications, electronic warfare and information warfare. He is also an advisor in the SIGINT technologies.

Manager, Defense Systems Technology Operation, SAIC (1989-1994).
Dr. Worch directed the activities of three Divisions involved in advanced research and development programs. The activities were primarily in the area of advanced C^3I and reconnaissance/surveillance technology with emphasis on sensor technology for the detection recognition of ground and air targets that are hidden or possess reduced observables characteristics. Dr. Worch served directly as a technical advisor to ARPA on numerous program areas relating to C^3I.

Manager, C^3I Technology Division, SAIC (1982-1989).
Dr. Worch was involved in operational and technical analyses as well as both strategic and tactical sensor, electronic warfare, and C^3I architecture studies corporate-wide. He conducted analyses and managed programs in relocatable targets, RPVs, reconnaissance systems, C^3I interface for advanced weapons systems, data links, smart weapons, navigation; LPI/LPE communications, electronic warfare and C^3CM. He was active in C^3I R&D for strategic, tactical and special operations forces

U. S. Air Force (1957-1981).
Dr. Worch served in numerous roles as an Air Force officer including both development and maintenance of communications and electronics systems; weapons systems; and avionics equipment of tactical and airlift aircraft. He served as project engineer responsible for research and exploratory development of electromagnetic signal reconnaissance techniques, communications and navigation projects at Rome Laboratory (formerly Rome Air Development Center). Dr Worch completed his service as Vice Commander of Rome Air Development Center at which he was principal assistant to the Commander and shared responsibility for command and direction of the Center research and development in command, control, communications and intelligence.

R&D Program Manager, Tactical Technology Office, DARPA (1973-1976).
Managed and technically directed multi-service exploratory development efforts of critical importance to defense programs. Initiated, planned, directed and evaluated programs in electronics intelligence, advanced communications, advanced LPI airborne radar, target identification, navigation, and low observables aircraft. Directed and participated in OSD studies, symposia and panels of technical and operational nature. Dr. Worch conceived and managed a program for precision emitter location from remotely piloted vehicles (RPV) and participated in RPV communications and sensor system developments. He formulated and directed programs in bistatic radar and low probability of intercept airborne radar.

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Transverse Mode Studies in a Helium-Neon Gas Laser, Oklahoma State University School of Electrical Engineering, Department Report, 1965.

MAJOR ADVISORY ACTIVITIES

2006 Co-Chair, AFSAB Summer Study, “Air Defense Against UAVs”

2005 Member, DARPA Study, “Vertical Dominance”

2005 Member, AFSAB Quick Look Study, “Automatic Target Recognition”

2005 Member, Air Force Operational Test and Evaluation Advisory Group

2005 Co-Chair, AFSAB Ad Hoc Study, “Domain Integration”

2004-2005 Member, DARPA J-UCAS Senior Advisory Group

2004 Vice Chair, AFSAB Summer Study, “Networking to Enable Coalition Operations”

2004 Member, Aerospace Command, Control, Intelligence, Surveillance, Reconnaissance Center (AC2ISRC) Commander’s Advisory Group

2004 Member, Air Combat Command Commander’s Advisory Group

2004 Member, Air Force Operational Test and Evaluation Center Commander’s Advisory Group

2003 Panel Chair, AFSAB Summer Study, “Unmanned Aerial Vehicles in Perspective”

2003 Chair, Air Force Special Operations Command Commander’s Advisory Group

2002 Chair, AFSAB Quick Look Study, “Low Observable Aircraft Maintenance Technologies”

2002 Member, AFSAB Summer Study, “Immediate Attack Deep in Hostile Territory”

2001 Chair, Concealed Targets Panel, AFSAB Summer Study, “Sensor Technology for Difficult Targets”

2000 Member, ASD C3I Joint Services Advisory Group (JSAG) on C3I

2000 Chair, AFSAB Summer Study, “Air Force Command and Control – The Path Ahead”

1999 Co-Chair, AFSAB Summer Study, “Technology Options to Leverage Aerospace Power In Other Than Conventional War Situations”

1998, 2000, 2006 Chair, AFSAB S&T Review of Sensor Programs

1998 Member, AFSAB Summer Study, “Aerospace Operations in the 21st Century: An Investment Strategy”

1997 Member, AFSAB Summer Study, “Global Air Navigation System”

1996 Chairman, AFSAB Summer Study, “UAV Technologies and Combat Operations”

1995 Member, Sensors Technology Panel, AFSAB Summer Study, *New World Vistas* Long Range Forecast

1995 Chairman, AFSAB Study, “F-22 Electronic Combat Effectiveness Testing”

1994 Member, SAB Ad Hoc Study on Technology Opportunities for Wide Area and Local Area Communications

1994-1996 Member, C^3I Science & Technology Panel, Air Force Scientific Advisory Board.

1994 Chairman, Special Missions Aircraft Panel, Air Force Scientific Advisory Board Summer Study, "Mission Support and Enhancement for the Forseeable Aircraft Force Structure."

1993 Member, C^3 Panel, Air Force Scientific Advisory Board Summer Study, "Options for Theater Air Defense"

1992-1993 Member, Air Force Studies Board "Committee on Counterforce Options Against Tactical Missiles"

1992 Member, Space and C^3I Panel, Air Force Scientific Advisory Board Summer Study, "Concepts and Technologies for Global Power - Global Reach"

1990-1991 Chairman, DARPA Advanced Targeting Technology Program Red Team

1991 Member, Communications Architecture Panel, Air Force Scientific Advisory Board Summer Study, "Off-Board Sensor Data to Support Military Combat Air Operations"

1985 Member, ECM, Sensors & Navigation Panel and C^3 Panel, Air Force Scientific Advisory Board Summer Study, "Enhancement of Special Operations Forces (SOF)"

1982 Member, C^3 Panel, Air Force Scientific Advisory Board Summer Study, "Enhancement of Airlift in Force Projection"

1978 Member, The Technology Cooperation Program (TTCP), Subgroup K, Radar Technology

1977-1979 Group Member and Subgroup Chairman, NATO Project 2000, Phase II. Study on Target Detection, Location and Identification

1975 Co-Chairman, Joint Services Emitter Identification Conference

1975 Panel Chairman, EUCOM Target Acquisition Seminar

1975-1976 Associate Member, Air Force Scientific Advisory Board Panel on TDOA Emitter Location Sorting

1975 Associate Member, Defense Science Board Task Force on Identification, Friend, Foe or Neutral

1975 Co-Chairman, DOD Integrated Tactical Information System Study Group

1975 Member, CIA Study Group on Precision Guided Munitions

1974 Chairman, DOD NAVSTAR Weapon Guidance Workshop

1974 Co-Chairman, Tri-Service Millimeter Wave Workshop

1974 Member, DOD Intelligence Research and Development Council Task Force on Intercept and Position Fixing

MISCELLANEOUS

Commercial Pilots License with Single, Multi-engine and Instrument Ratings
First Class Radiotelephone License
Senior Member, IEEE
Member, Eta Kappa Nu

Top Secret and SCI Clearances

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